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LASER PUMPING SOURCES

Third Quarterly Technical Report

1.0 EXPLOSIVELY SHOCKED GASES

Two modifications in the driver method were made to establish that the early quenching of the radiation pulse is caused by mixing processes. The first modification simply directed the explosive blast transverse to the shock tube axis. Small solid particles generated in the blast were thus directed transverse to the tube and were momentarily trapped in a small cavity in the opposite side wall of the tube. This small modification resulted in a surprisingly large change in the measured spectral properties of the gas. The large fluctuations in luminosity in the incident shock heated gas and also in the reflected shock heated gas disappeared. The absolute brightness temperature ranged from 11,000°K in the violet to 15,000°K in the red region of the spectrum, consistent with computed gas temperatures, and in sharp contrast to the results obtained previously using the axially directed blast (8000°K at 4100 A, 13,000°K at 5600 A, and 24,000 to 32,000°K at 6800 A). On the basis of these results it is concluded that explosive products (probably small solid particles) mix with the shock heated xenon, produce fluctuations in luminosity, cause high radiation intensities in the red region of the spectrum (due possibly to chemiluminescence), and result in early quenching of the radiation pulse. This conclusion was further verified by subsequent experiments utilizing the gaseous combustion driver as described below.

Using the transverse directed blast a series of experiments at varying initial xenon pressure were made to ascertain the deleterious effects caused by ablation of the lucite window. It was found that the radiation pulse duration increased with increasing initial pressure at roughly fixed initial shock Mach number. From this it is concluded that ablation of the lucite window produces no measurable attenuation of radiation at 5600 A when in contact with xenon at 12,000°K, 9,000 psi, for a duration up to 60 μsec.

Using the transverse directed blast an attempt to stimulate laser oscillation in a 1/4" x 2" ruby was made but was unsuccessful because of the short (60 μsec) radiation pulse.

To further reduce the quenching effect caused by explosive products, experiments utilizing a gaseous combustion driver have been initiated. A stoichiometric mixture of hydrogen and oxygen diluted with 80 mole percent helium at an initial pressure of 250 psia is ignited with an exploding wire. The pressure rise breaks a prescribed copper diaphragm driving a shock at about Mach number 8 through the xenon. This driver technique results in a radiation intensity after shock reflection of 9000°K to 10,000°K (at 5600 A), lasting 200 μsec. Sudden quenching at 200 μsec occurs, probably caused by small pieces of the diaphragm broken in the experiment. This further verifies the effect of explosive products quenching the shock heated xenon. It also shows the lucite window to be capable of transmitting radiation in excess of 200 μsec, greatly increasing the overall energy conversion efficiency.

Further studies are being directed toward increasing the radiation intensity by utilizing lower initial gas pressures, driven by the gaseous combustion source. The possibility of spectral tailoring is being studied theoretically. Fast burning solid propellant materials for use as shock drivers will be evaluated to determine if these are relatively free from solid particle material. Further attempts to stimulate laser action in ruby material will also be carried out.

2.0 EXPLOSIVE PYROTECHNIC STUDIES

Three tests were performed in which the objective was to intensify the irradiance of the Zr-O_2 reaction by impinging a shock wave upon the combusting metal. A two inch rod of lead styphnate containing a 3 mil nichrome wire was embedded in a three inch length of wool. This combination was placed in a ½ inch diameter lucite tube. The tubes were pressurized to 10 atm O_2 and ignited with 2 joules electrical energy. Brightness temperatures at 5600 Å were measured. In the first two runs, the nichrome wire was connected to the energy source, in the third the nichrome wire circuit was open. Absolute spectral data were obtained on only the second test where a brightness temperature of 2720°K was recorded. Observers reported the other two runs gave approximately the same irradiance. Additional firings for this configuration are planned. They will not have a wire in the lead styphnate and, therefore, should ignite at a more useful time, i.e., as the metal is combusting.

Barium peroxide, BaO_2, and strontium nitrate, $(Sr(NO_3)_2$, powders were injected into the oxygen line of an oxy-hydrogen burner.

Order of magnitude flow for BaO_2 was 55 mg/sec. Optimum light intensity was attained by manual control and visual observation. Spectral brightness data were obtained with a spectrophotometer. BaO_2 gave emission lines at 5535 and 5347 Å, but brightest emission was given over a broad spectrum around 5137 A. The brightness temperature of this band varied from 2550 to 2750°K. Only one of the three emission lines for strontium was observed because of the spectrophotometer's limited range. It was the 6060 Å line. The measured brightness temperature was 3120° to 3300°K. If these measurements were not in error then some chemiluminescence in the Sr flame was observed. The temperature of an oxy-hydrogen flame at atmospheric pressure is at most 3070°K. This work was a prelude to a program in which chemiluminescence was sought by injecting vaporized materials into an oxygen atmosphere.

Elemental boron and barium and also C-2 explosive were explosively driven through a small nozzle into ten atmospheres oxygen. Altogether 5 tests were performed. Two tests used 50 mg B, one 20 mg B, one 96 mg Ba; all of these had a 167 mg PETN charge. 257 mg of C-2 was injected by 130 mg PETN. None of the tests produced enough light to expose spectrographic film. No absolute brightness temperatures were recorded because of low intensities. Orifice diameters varied from 0.040 to 0.125 inch. Observers noted low intensity blue to blue-white flames for two B runs, a yellow flame for the third, and a green flame for the Ba run. No observation was made of the C-2 run.

A comparison of peak irradiance developed by the $Zr\text{-}O_2$ reaction when enclosed in either lucite tubes or glass lined lucite tubes showed no real difference between the two configurations.

Three $Zr\text{-}O_2$ reactions were set off in lucite hardware having cylinder walls and end caps 0.5 inch thick. It was hoped high pressures could be obtained in this constant volume system (ullage volume 13% of total). Theoretically, if peak pressures of 200 atmospheres can be reached, the equilibrium reaction temperature would approach 6500°K. To date the highest pressure recorded has been 78 atm and the highest temperature 4450°K. Future work will include improvement in design and assembly procedure to achieve higher pressures and addition of salts, e.g., $Ba(NO_3)_2$, $CsNO_3$, to improve optical thickness and emissivity.